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**Spectral and Broadband Rotating Shadowband
Shortwave Radiometry and Analysis**

DE-FG02-90ER61072

A focal point of this research is to improve shortwave filter radiometers and spectroradiometers and their calibration. The multi-filter rotating shadowband radiometer (MFRSR) and rotating shadowband spectroradiometer (RSS) were developed through the ARM Program. Improvements in the RSS continue as an integral component of our research. Another component of our research is more accurate radiometric measurements using commercial instrumentation. Key to improved broadband and spectral measurements is a better understanding of calibration sources and procedures. Better broadband and spectral data are used to spur improvements in the theoretical treatment of radiative transfer in the atmosphere through measurement and model comparisons. Better measurements have not only provided basic radiometric data, but have also led to the development of remote sensing techniques that permit the retrieval of parameters that are critical to climate change studies. We have had successes in the retrieval of total column aerosol optical depth, total column water vapor, cloud optical depth and mean photon pathlength. We continue to improve these retrievals as we add other retrieved species, such as total column ozone and photochemical products. A new role that we have taken on is that of providing broadband and spectral calibrations for the instruments mounted on the aircraft and ground for the ARM UAV program. Pre- and post-flight calibrations are seen as critical in validating the measurements made during the airborne phase of measurement campaigns.

Accomplishments

- The rotating shadowband radiometer was used at the North Slope of Alaska during the March 1999 Water Vapor IOP to measure visible and near-infrared spectra primarily for the purpose of retrieving water vapor. Initial results shown at the ARM 2000 meeting indicate very close agreement with the 183-GHz microwave radiometer water vapor retrievals in these extreme, low water vapor conditions.
- Several methods to correct for the offsets in thermopile pyranometers used for the measurement of shortwave diffuse irradiance were tested in collaboration with colleagues within and outside the ARM program. The preferred procedure depends on the particular configuration used for the diffuse measurement. A preliminary procedure for the ARM configuration has been selected. Black and white pyranometers appear to be a viable choice for a zero-offset diffuse pyranometer.

- Shortwave calibrations for the ground-based and aircraft-based spectral and broadband radiometers used for the ARESE II IOP were provided. Spectrometers and radiometers were calibrated before and after the mission using standard lamps for the spectrometers and an outdoor BSRN procedure for the broadband radiometers.
- A new differential technique to retrieve column water vapor from the MFRSR, from several channels of the RSS, or from any qualified sun radiometer was developed and tested against other optical and microwave techniques. The strength of the method is that it does not require a modified-Langley calibration, which may be difficult to obtain because of site-dependent water vapor column instability.
- Colleagues at AER, Inc. have begun comparisons among RSS measurements of direct and diffuse irradiance and the Code for High Resolution Accelerated Radiative Transfer (CHARTS). Results suggest that there are no unaccounted for narrow spectral features in the code, but the model underestimates diffuse irradiance, not direct irradiance, unless aerosols are more absorbing than collateral measurements suggest.
- The first International Pyrgeometer and Absolute Scanning Radiometer Comparison (IPARSC-I) was conducted in the fall of 1999 at the SGP site. Calibrations using a blackbody to calibrate the pyrgeometers were improved four-fold using nighttime comparisons to all-sky measurements of the absolute scanning infrared radiometer of the World Radiation Center in Davos, Switzerland.
- The ARM SGP central facility has performed measurements of aerosol optical depth using the MFRSR since 1992. A paper showing the seasonal and inter-annual behavior for this and two other sites with long-term records was submitted for publication.
- Photon pathlength retrievals using the 760-nm molecular oxygen band as measured by the RSS are combined with cloud optical depth retrievals using the MFRSR. Scatterplots of pathlength versus cloud optical depth reveals two distinct cloud configurations; one for single-layer clouds and the other for multiple cloud decks. Statistics of the cloud properties can be developed that allow the testing of the representativeness of GCM cloud-diagnostic schemes.
- Using NIST spectral irradiance standards we have developed a working standard for calibrating the RSS. This calibration yields the spectral irradiance per count. Through Langley analysis we can estimate the response of our RSS in counts at the top of the atmosphere. By multiplying the calibration and the extraterrestrial response we estimate the extraterrestrial (ET) solar spectral irradiance. Comparisons with the Kurucz spectrum used in many models suggest that there is a discrepancy in parts of the visible spectrum that are as large as 4-5% near 480 nm. We are working to corroborate these preliminary results that would have a significant impact on measurement and model comparisons.

Progress

Progress continues in improving basic shortwave radiometry and spectroradiometry and in retrieving aerosol and water vapor in clear atmospheres and cloud properties in overcast conditions. Our research is conducted jointly with six other groups including other members of the ARM science team as well as others in the scientific community.

Our broadband shortwave effort continues to center on a search for improvements in the measurement of diffuse horizontal irradiance and corrections of past measurements. The disagreement between clear-sky measurements and models appears to be primarily in the diffuse component of downwelling radiation. Thermopile pyranometers (in ARM, the Eppley PSP) have offset errors because the thermopiles also respond to longwave radiation. An imbalance between the temperature of the receiver and that of the inner dome that covers the receiver leads to a significant negative offset on clear days. The intermediate correction is to develop a linear relation between the nighttime offset and the net thermopile signal in the PIR, which correlates with the response of the thermopile in the PSP. Since we expect this offset to be zero as the net pygeometer signal approaches zero, we force the linear relationship through zero at zero net infrared. Applying this correction eliminates the offset to within about 5 W/m^2 in the mean.

The long-term solution to this problem is to use a pyranometer that does not have a significant offset. The Eppley 8-48, also called the Black & White (B&W), has hot and cold junctions under black and white surfaces that are exposed to the same thermal environment. Since the system is nearly balanced, their response is nearly zero if there is no shortwave radiation on the detector surface. We have verified this performance at night, but must confirm that the performance is correct during the daytime. This has been to some extent substantiated in the paper by Dutton and co-authors (in the publication list). The Eppley B&W agrees with the Eppley PSP after correction of the latter to within 5 W/m^2 . We are in the process of comparing measurements from NASA Langley Research Center's PSP whose internal dome and case temperatures are measured and then used to correct the thermal offset directly.

Spectral analyses using the 512-channel, silicon diode array-based and 1024-channel, CCD-based rotating shadowband spectroradiometers (RSS) took most of our effort this year. We continue to refine the data quality through calibrations that use spectral irradiance lamps and through Langley analyses. We collaborated with our ARM colleagues at AER to compare their CHARTS model with our 512-channel RSS measurements during the 1997 Shortwave IOP. We used the same IOP data to retrieve total column water vapor from the RSS spectral data in the 940-nm water vapor band. In addition, RSS measurements made in March 1999 at the Water Vapor IOP at the North Slope of Alaska are being used to retrieve water vapor for the very dry conditions of the Arctic winter.

We took part in the ARESE II experiment this past winter and spring providing the calibration for spectral radiometers and broadband shortwave radiometers both before and after the flight portion of the experiment. For the spectral measurements we transferred a calibration to our three EG&G 1000 W FEL lamps over the wavelengths 300 to 2400 nm using an NREL spectrometer. This transfer is based on six ARM NIST lamps. We confirmed our earlier results to within 1% for the 300-1100 nm range where we used only three of these NIST lamps. The six

NIST lamps gave a total spread of 4% compared to their 1% stated accuracy, but the mean was consistent with the previous mean to 1%. The differences were again wavelength independent suggesting a problem with the geometry of the transfer measurement at NIST. Each of the three calibrated lamps irradiated the NASA-Ames spectrometer, the CSU spectrometer, and the UCSD TDDR filter radiometer before these instruments were mounted on the Otter and after the experiment. We constructed a temporary darkroom at the Ponca City Airport for this purpose.

For the broadband calibrations before and after the flight portion of the mission we performed side-by-side comparisons with all participating ARESE II broadband devices in a zenith-pointing configuration at the Blackwell-Tonkawa airport. We moved the NREL-provided calibration system to the SGP central facility during the flight portion of the experiment. Our calibration setup included an ARM cavity radiometer and an Eppley NIP for direct solar irradiance (the cavity was only used on selected clear days). The diffuse horizontal solar irradiance was measured with an Eppley 8-48 (black and white) pyranometer, and an Eppley PSP pyranometer was used for backup. The PSP measurements are corrected for offsets using simultaneous measurements from an Eppley PIR pyrgeometer. The cavity direct and 8-48 diffuse were summed for the total horizontal irradiance. If the cavity was not operating, we substituted the Eppley NIP data. The 8-48 operated without interruption throughout the campaign.

Broadband measurements of direct normal irradiance generally agree with broadband models of direct normal irradiance, but broadband model predictions of diffuse horizontal irradiance exceed diffuse horizontal irradiance measurements for clear-sky conditions. It is important to understand where in the spectrum the models disagree with measurements of diffuse irradiance. Moreover, it is important to check that the agreement in direct models and measurements is not a result of error compensation in different portions of the spectrum. Toward this end we are cooperating with ARM colleagues from AER (Clough, Mlawer, and Brown) and PNNL (Shippert) by providing RSS spectral data and guidance in using the data that they compare to their CHARTS model for the 350-1080 nm range covered by the RSS. For the cases studied thus far the agreement is close throughout the direct solar spectrum. The diffuse spectral models and measurements agree, but the single-scattering albedo of the aerosols required for these matches tends to be lower than surface-based in situ measurements and calculations of this parameter suggest. This is consistent with the conclusions obtained for the broadband comparisons. Aside from a wavelength dependent offset the spectral details are well matched in these comparisons. This hints that the source of the difference is in the aerosol specification in the model, not in any missing molecular species.

The modified-Langley technique introduced by Reagan and colleagues (IGARSS, IEEE, Ann Arbor, Michigan, 1987) is currently the preferred method for retrieving column water vapor using sun radiometers. To apply this procedure requires a stable column of water vapor under clear skies. Unfortunately, this condition occurs even less frequently than the stable aerosol column necessary for the typical Langley plots required for aerosol retrievals. To get around this stability requirement we developed a differential technique that requires only knowledge of the relative response between a channel in the water band and one near in wavelength, but outside the water band. The details are given in a paper that is in its second review in the Journal of Geophysical Research-Atmospheres.

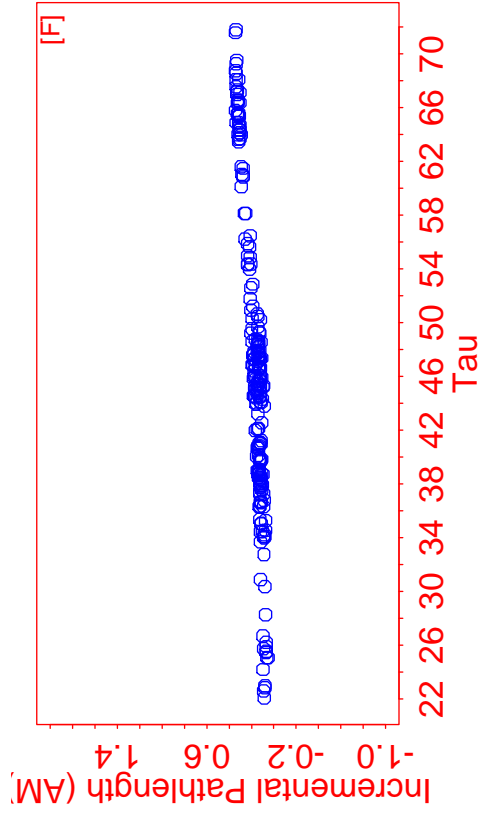
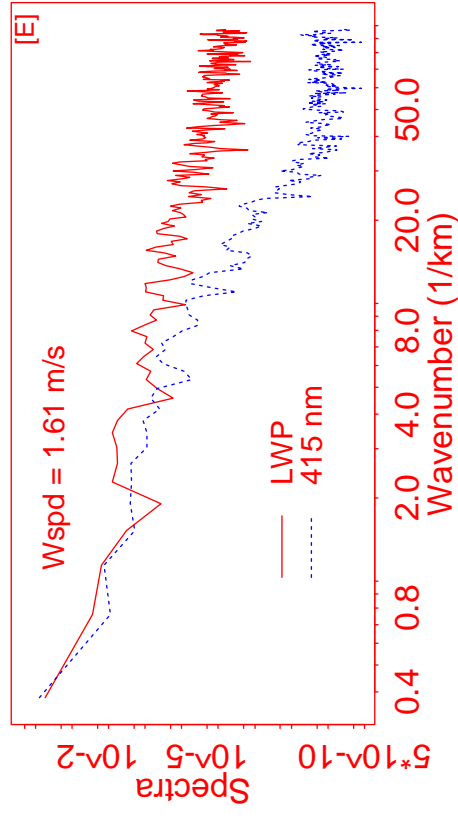
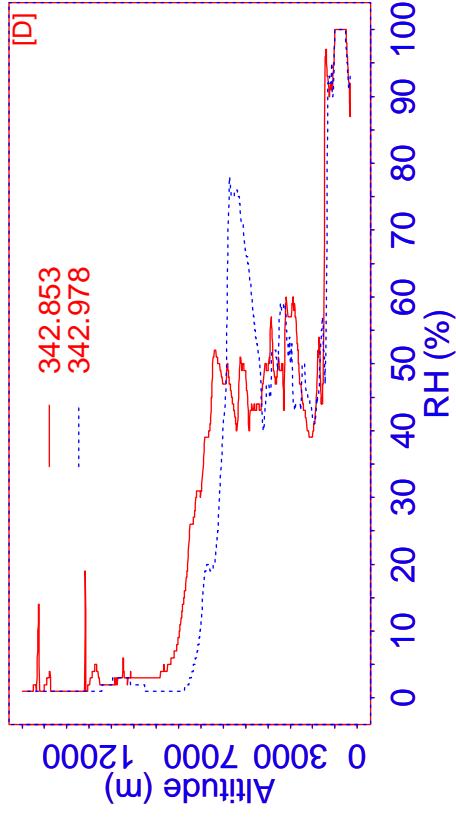
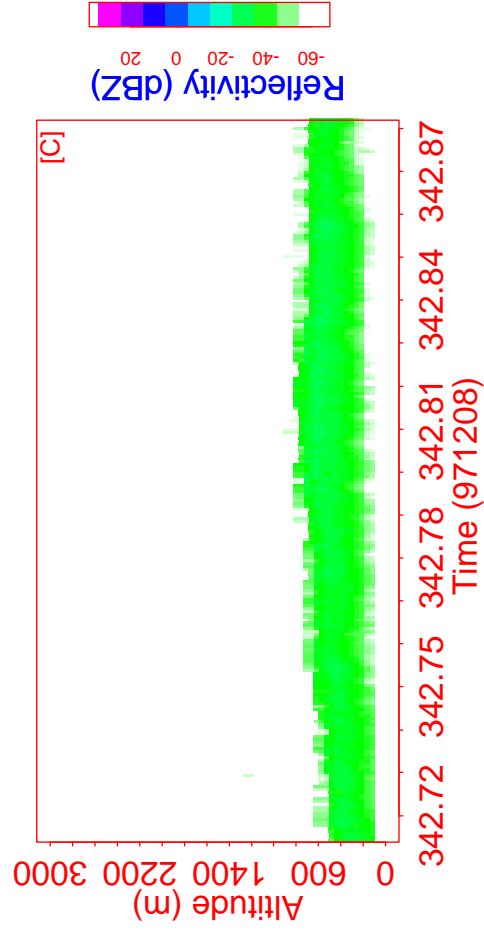
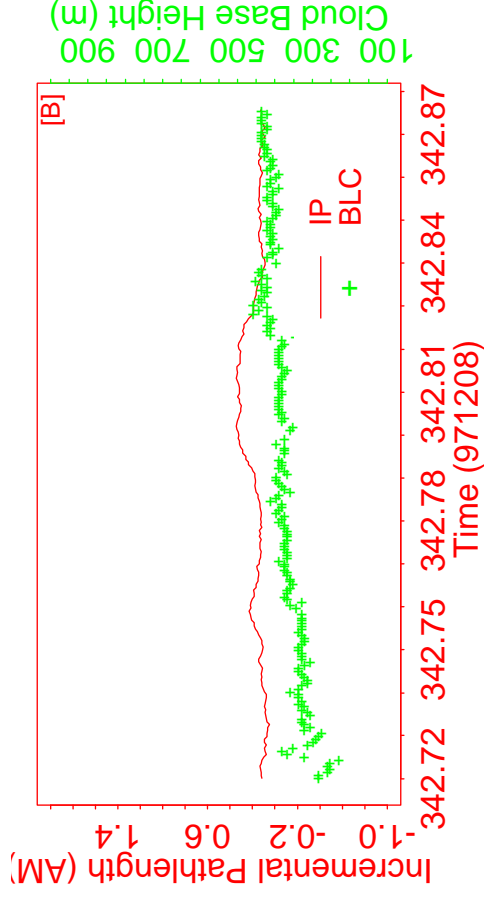
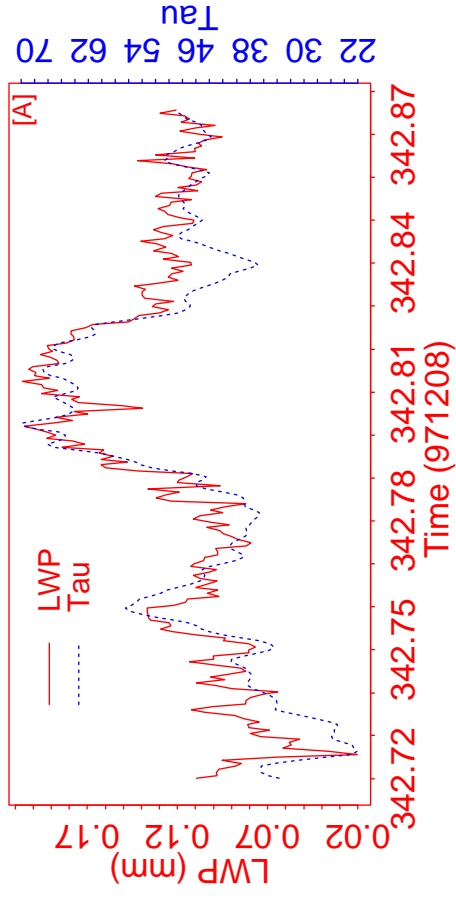
We have applied this technique to the RSS spectra and the MFRSR filter measurements from the 1997 Water Vapor IOP. In a paper by Schmid and colleagues we compare these results with three other optical retrievals and with microwave radiometer (MWR) retrievals. Curiously, before a recent discovery of a problem with the line strengths of the 940-nm water vapor band used for these retrievals (Giver et al., JQSRT 66, 101-105, 2000), we had a spread of less than 0.2 cm among the results. With the corrected line strengths we now have a spread of almost 0.4 cm among the results. Clearly, there is still some work to be done to resolve the difference between the 23.8-GHz MWR and the optical retrievals at the high and moderate water vapor amounts experienced at the SGP.

On the other hand, we have two independent results from the North Slope of Alaska during the March 1999 Water Vapor IOP that have compared favorably at very low total water vapor columns between 0.5 and 2 mm. In this case, a simple optical technique was applied to the 940-nm water vapor band using RSS data and compared with 183-GHz microwave radiometer results obtained by Raccette and colleagues. This paper is in preparation.

We have studied photon pathlengths, cloud morphology and homogeneity, and radiation smoothing under various cloud conditions. Using high time-resolution data streams from collocated instruments at the ARM SGP site, we can focus on the large-scale fluxes and transmittances that are the important quantities for cloud overlap schemes and sub-grid parameterizations in GCMs. The instruments used include broad- and narrow-band radiometers, a MWR, a balloon-borne sounding system (BBSS), millimeter-wave cloud radar (MMCR), a micropulse lidar, and a ceilometer.

The figure on the next page shows an example of a single thick cloud case on December 8, 1997. The liquid water path measured from a MWR and the cloud optical depth inferred from a MFRSR are plotted to overlap each other as shown in panel A. This panel illustrates that the large scale structures are well correlated and fluctuate in phase with each other. This further implies that the variation in effective radius is relatively small. The cloud base height is plotted in panel B, along with the incremental pathlength, showing that the cloud base height changed gradually from 200 m in the early morning to 400 m in late afternoon. The MMCR reflectivity, shown in panel C, illustrates that there was a single stratus cloud layer with a nearly constant cloud geometric thickness of 500 m over the entire period. Two relative humidity profiles taken from the BBSS in the afternoon, shown in panel D, confirm that there was only a single cloud layer.

For this low-level stratus cloud the photons transit nearly the full direct-beam pathlength before encountering the cloud, the incremental pathlength (the total pathlength minus the direct-beam pathlength) is the enhanced pathlength due to clouds. Joint statistics of incremental mean pathlength and cloud optical depth are shown in panel F. It shows good correlation with cloud optical depth with slight modulation by cloud base height (panel B). This case is illustrative of many single-layer cloud cases where the pathlength scales linearly with optical depth (in this case over the range 20 to 70) thus exhibiting the Brownian diffusion limit for fixed physical depth. In general the physical depth of the cloud, or altitude (important because the retrieval is pressure-weighted) may be correlated with optical depth, which would alter the apparent slope.



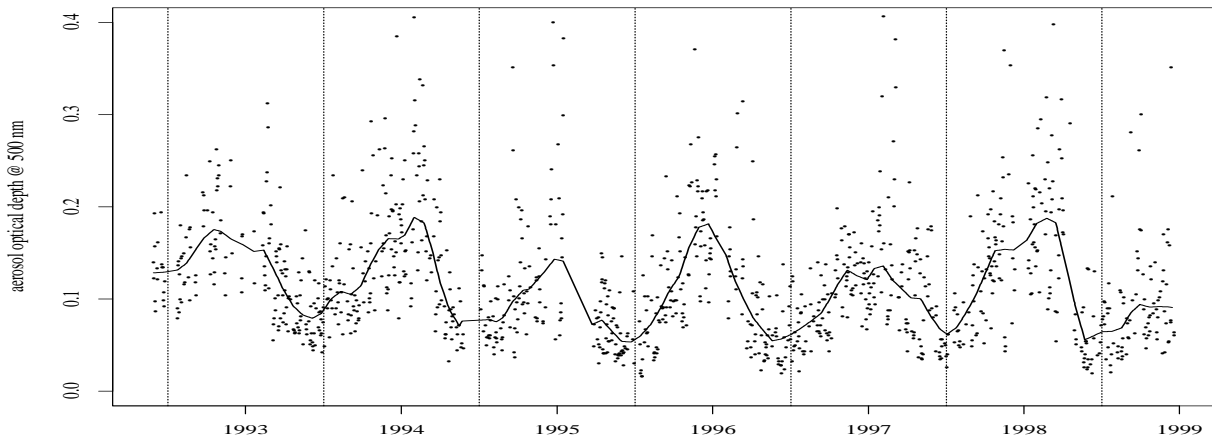
Panel E shows the log-log plot of normalized wavenumber spectra for the LWP and the transmittance at 415 nm from the MFRSR measurements. The mean wind speed at cloud level was 1.61 m/sec, allowing us to characterize the wavenumber spectra for the range 0.3 to 80 km⁻¹. The LWP spectrum follows a power-law statistic $k^{-\beta}$ with a β of 1.89, reflecting a statistical scale invariance over scales from 20 m to several kilometers. The spectrum of the narrow band transmittance at 415 nm illustrates a scale break around 3 km⁻¹ indicating a change in the dominant physical process in the radiation field -- multiple scattering. While at the scales larger than the break point, the radiation field follows variations of LWP of clouds, at the smaller scales it shows much smoother behavior with an exponent β of 4.09. Panel A clearly shows the smoothness of the radiation field compared to the cloud LWP field. Simply taking the ratio of LWP and transmittance spectra, we see a nice low-pass filter. It illustrates that the effect of multiple scattering on the transfer of radiation is to filter smaller scale structure leaving the radiance dependent only on the grossest scales [Stephens JAS 45, 1818-1848, 1988; Marshak et al. JGR 100, 26247-26261, 1995].

In a paper recently submitted to the Journal of Geophysical Research-Atmospheres we describe our methodology for producing aerosol optical depths from the MFRSR, which can, in fact, be applied to any sun radiometer. The critical point is that we obtain a robust estimate of the calibration of the instrument using the available Langley plots obtained on site. This allows us to keep the instrument in calibration despite changes in instrument response caused by monotonic filter deterioration, for example, or slow changes in the transmission of the optics due to soiling, as another example.

The next figure contains results from the ARM SGP central facility. The top panel contains daily-averaged aerosol optical depths obtained by averaging all cloud-screened, 30-minute averages during the day. The number of daily values is slightly less than one every other day with a reasonable distribution of points throughout the year. A smoother through the points makes it clear that there are summer peaks and winter minima. The winter minima stabilize in the later years after decreasing from a higher value associated with the stratospheric loading brought about by the eruption of Mt. Pinatubo. The middle panel illustrates that the aerosol optical depth decreases with increasing wavelength in a consistent pattern. The bottom panel is a plot of the exponent in the fit of the equation $\tau = \beta\lambda^{-\alpha}$, where τ is the aerosol optical depth as a function of wavelength λ . α is an indicator of particle size with small α indicative of larger particles and an α of 4 indicating the limit of very small Rayleigh scattering particles. Winter particles have a larger mean size than summer particles, and there is an overall decrease in particle size as the stratosphere slowly sheds the larger Mt. Pinatubo aerosol particles.

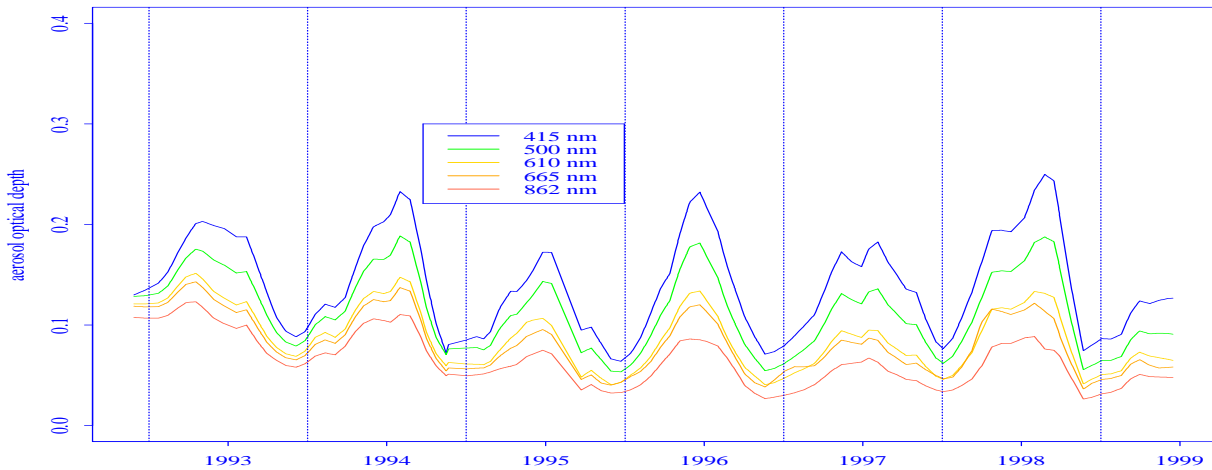
We co-arranged and participated in an IOP to calibrate and compare pyrgeometers in the fall of 1999. The first International Pyrgeometer and Absolute Scanning Radiometer Comparison (IPASRC-1) included a calibration in Boulder with the NOAA-CMDL blackbody followed by side-by-side measurements at the SGP central facility including the World Radiation Center's absolute scanning infrared radiometer and 15 pyrgeometers from BSRN members. The results were a spread of only 2.4 W/m² among 15 pyrgeometers after calibration to the WRC radiometer. This marks an order of magnitude improvement in uncertainty since the beginning of the ARM Program.

ARM-Oklahoma Aerosol Optical depth vs Time



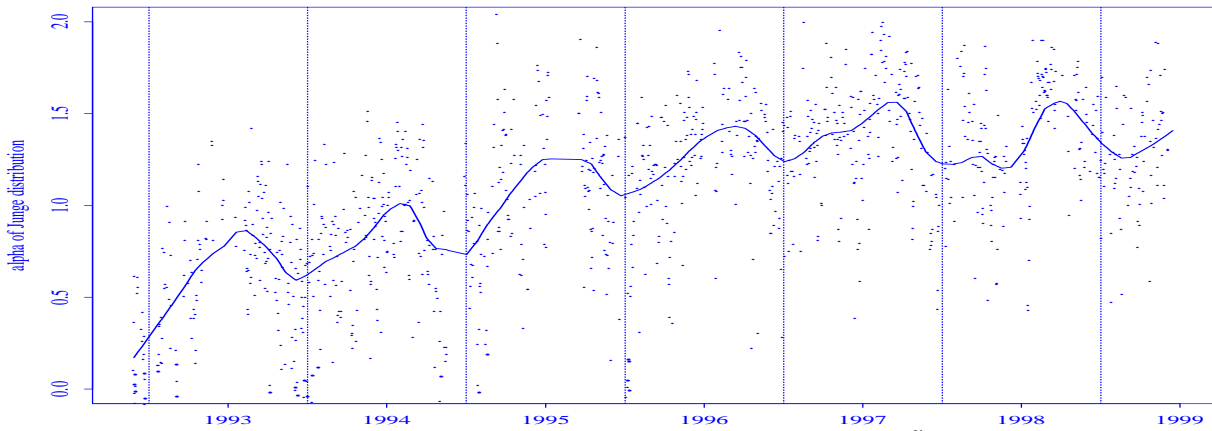
Daily-averaged aerosol optical depth at 500 nm with smoother applied to show seasonal and interannual variability. Note the summer peaks and winter minima.

ARM-Oklahoma Aerosol Optical Depth vs Time and Wavelength



Smoothed time series of aerosol optical depths for five wavelengths. Optical depth decreases with wavelength.

ARM-Oklahoma Wavelength Dependence vs Time



Wavelength dependence of the aerosol using the wavelength exponent in the equation $\tau = \beta\lambda^{-\alpha}$. Note the general decrease in particles sizes over the years and the winter and summer differences with larger aerosol in winter.

Publications (Refereed Papers)

Schmid, B., J. Michalsky, R. Halthore, M. Beauharnois, L. Harrison, J. Livingston, P. Russell, B. Holben, A. Smirnov, and T. Eck, Comparison of Aerosol Optical Depth from Four Solar Radiometers During the Fall 1997 ARM Intensive Observation Period, *Geophysical Research Letters*, 26, 2725-2728, 1999.^(a)

Mlawer, E.J., S.A. Clough, Brown, P.D., L. Harrison, J. Michalsky, P. Kiedron, and T.R. Shippert, Comparison of Spectral Direct and Diffuse Solar Irradiance Measurements and Calculations for Cloud-Free Conditions, submitted to *Geophysical Research Letters*.

Dutton, E.G., J.J. Michalsky, T. Stoffel, B.W. Forgan, J. Hickey, D.W. Nelson, T.L. Alberta, and I. Reda, Measurement of broadband diffuse solar irradiance using current commercial instrumentation with a correction for thermal offset errors, submitted to *Journal of Atmospheric and Oceanic Technology*.

Min, Q. and L.C. Harrison, Joint Statistics of Photon Pathlength and Cloud Optical Depth: Case Studies, submitted to *Journal of Geophysical Research*.

Michalsky, J., J. Schlemmer, W. Berkheiser III, J. Berndt, L. Harrison, N. Laulainen, N. Larson, and J. Barnard, Multi-Year Measurements of Aerosol Optical Depth in the Atmospheric Radiation Measurement and Quantitative Links Programs, submitted to *Journal of Geophysical Research*.

Michalsky, J.J., Q. Min, P.W. Kiedron, D.W. Slater, and J.C. Barnard, A Differential Technique to Retrieve Column Water Vapor Using Sun Radiometry, submitted to *Journal of Geophysical Research*.

Schmid, B., J. Michalsky, D. Slater, J.C. Barnard, R.N. Halthore, J. Liljegren, B. Holben, T. Eck, J. Livingston, and P. Russell, Comparison of Columnar Water Vapor Measurements During the Fall 1997 ARM Intensive Observation Period: Solar Transmittance Methods, submitted to *Applied Optics*.

Presentations (extended abstract included ✓)

Brown, P.D., S.A. Clough, E.J. Mlawer, T.R. Shippert, F. Murcray, J. Michalsky, L.C. Harrison, and P. Kiedron, High Resolution Model/Measurement Validations of Direct and Diffuse Flux in the Shortwave, *Proceedings of the Tenth Conference on Atmospheric Radiation*, American Meteorological Society, Madison, Wisconsin, June 28-July 2, 1999.

(a) Note: Schmid et al. (first item in refereed list) was in press for last report; it was included in list with final publication information and copies of publication.

Dutton, E., T. Stoffel, J. Michalsky, D. Nelson, and J. Hickey, Measurement of Broadband Diffuse Solar Irradiance: An Evaluation of Some Current Capabilities, Proceedings of the Tenth Conference on Atmospheric Radiation, American Meteorological Society, Madison, Wisconsin, June 28-July 2, 1999.

Harrison, L.C., Q. Min, and J. Michalsky, Spectral Measurements of Direct/Diffuse Solar Irradiance at the Southern Great Plains ARM Site: Analysis of Data from the Rotating Shadowband Spectroradiometer (RSS), Proceedings of the Tenth Conference on Atmospheric Radiation, American Meteorological Society, Madison, Wisconsin, June 28-July 2, 1999.

Michalsky, J.J., B. Schmid, R.N. Halthore, C.F. Pavloski, T.P. Ackerman, M.C. Beauharnois, L.C. Harrison, J.M. Livingston, and P.B. Russell, Comparison of Sunphotometric Measurements During the Fall 1997 ARM Intensive Observation Period, Proceedings of the Tenth Conference on Atmospheric Radiation, American Meteorological Society, Madison, Wisconsin, June 28-July 2, 1999.

Min, Q. and L.C. Harrison, Joint Statistics of Photon Pathlength and Cloud Optical Depth: Case Studies, Proceedings of the Tenth Conference on Atmospheric Radiation, American Meteorological Society, Madison, Wisconsin, June 28-July 2, 1999.

Brown, P.D., S.A. Clough, E.J. Mlawer, T.R. Shippert, F. Murcray, J. Michalsky, L.C. Harrison, and P. Kiedron, High Resolution Model/Measurement Validations of Direct and Diffuse Flux in the Shortwave, International Union of Geodesy and Geophysics XXII General Assembly, Birmingham, United Kingdom, 18-30 July 1999.

Michalsky, J., L. Harrison, M. Beauharnois, Optical Depth Spectra Based on the Rotating Shadowband Spectroradiometer, International Union of Geodesy and Geophysics XXII General Assembly, Birmingham, United Kingdom, 18-30 July 1999.

Michalsky, J., Multi-Year Measurements of Aerosol Optical Depth in the Atmospheric Radiation Measurement and Quantitative Links Programs, American Geophysical Union Fall Meeting, San Francisco, California, 13-17 December 1999.

Harrison, L., Q. Min, P. Kiedron, J.J. Michalsky, J. Schlemmer, J.C. Barnard, and D. Slater, Spectral Optical Depths and Clear-Sky Direct/Diffuse Ratios at SGP, Proceedings of the Tenth Atmospheric Radiation Measurement Science Team Meeting, San Antonio, Texas, March 13-17, 2000.

Kiedron, P. and J.J. Michalsky, Polarization Sensitivity of Diffusers Used in MFRSR and RSS and Diffuse Irradiance Error, Proceedings of the Tenth Atmospheric Radiation Measurement Science Team Meeting, San Antonio, Texas, March 13-17, 2000.

Kiedron, P., J. Michalsky, Q. Min, and D. Slater, Robust Retrieval of Precipitable Water Vapor at NSA Using the Rotating Shadowband Spectroradiometer, Proceedings of the Tenth Atmospheric Radiation Measurement Science Team Meeting, San Antonio, Texas, March 13-17, 2000.

Lesins, G., Q. Fu, and J.J. Michalsky, Some Results and Unresolved Issues from 5 Years of Clear-Sky Solar Radiation Measurements at the SGP Site, Proceedings of the Tenth Atmospheric Radiation Measurement Science Team Meeting, San Antonio, Texas, March 13-17, 2000.

√Michalsky, J.J., P. Kiedron, J. Berndt, T. Stoffel, D. Myers, I. Reda, A. Andreas, ARESE II Spectral and Broadband Shortwave Absolute Calibrations, Proceedings of the Tenth Atmospheric Radiation Measurement Science Team Meeting, San Antonio, Texas, March 13-17, 2000.

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Mlawer, E.J., P.D. Brown, S.A. Clough, L. Harrison, J. Michalsky, P. Kiedron, and T.R. Shippert, Comparison of Spectral Direct and Diffuse Beam Measurements and Calculations, Proceedings of the Tenth Atmospheric Radiation Measurement Science Team Meeting, San Antonio, Texas, March 13-17, 2000.

Philipona, R., E. Dutton, T. Stoffel, J. Michalsky, I. Reda, P. Wendling, and A. Stifter, The International Pyrgeometer and Absolute Scanning-Radiometer Comparison, IPASRC-I, Proceedings of the Tenth Atmospheric Radiation Measurement Science Team Meeting, San Antonio, Texas, March 13-17, 2000.

√Schmid, B., J. Michalsky, D. Slater, J.C. Barnard, R.N. Halthore, J. Liljegren, B. Holben, T. Eck, J. Livingston, and P. Russell, Comparison of Columnar Water Vapor Measurements During the Fall 1997 ARM Intensive Operational Period: Optical Methods, Proceedings of the Tenth Atmospheric Radiation Measurement Science Team Meeting, San Antonio, Texas, March 13-17, 2000.

Michalsky, J., J. Schlemmer, W. Berkheiser III, J. Berndt, L. Harrison, N. Laulainen, N. Larson, and J. Barnard, Multi-Year Measurements of Aerosol Optical Depth: Field Calibration, Seasonal and Interannual Variability, 6th Baseline Surface Radiation Network Meeting, Melbourne, Australia, 1-5 May 2000.

Expected Research in FY 2001

ARESE II calibration data will be analyzed with special attention to the differences in the direct irradiance measured with the absolute cavity radiometer and with the Eppley pyrheliometer. Most of the data were acquired with the Eppley NIP. On some days the NIP read higher than the cavity and on others the situation was reverse. It may be that the slight differences in field-of-view are giving rise to this variability. We are also examining the corrected Eppley PSP versus the Eppley Black and White that were both used to measure diffuse for this experiment. The sum of direct and diffuse on a horizontal surface is being used to calibrate all broadband radiometers used in the experiment. Comparisons will be made among all of the instruments after these calibrations are applied.

We expect to spend more time on the shortwave broadband diffuse issue. We will compare our Eppley Black and White data obtained during the ARESE II experiment with the Haeffelin Eppley PSP that has thermistors attached to the inner dome and case to directly measure the temperatures that cause the offset. Based on the outcome we may have a more definitive recommendation for the diffuse measurements in the future. We also expect improvements to the current recommendation regarding a correction to the past ARM PSP-based data record.

In regard to diffuse horizontal irradiance measurements we are proposing an IOP for the fall of 2001 that will ask members of the BSRN and ARM communities to send diffuse pyranometers to the ARM SGP site. We wish to compare corrected diffuse measurements in order to examine whether we have reached a consensus with regard to this elusive measurement.

Spectral calibration in the shortwave is becoming more of an issue. If we base our calibration on the six ARM NIST lamps, this gives the RSS a responsivity in terms of instruments counts per spectral irradiance input. If we then use Langley plots to get a robust estimate of the extraterrestrial RSS response in terms of instrument counts, then we can estimate extraterrestrial irradiance. Our results show up to 5% differences in the 480-nm region compared with the Kurucz solar spectrum. This difference could explain about 10 W/m² differences in models based on Kurucz and measurements based on our calibrations, therefore, it is important to resolve these differences. In fact, this year we are beginning to move away from lamp-based standards for the shortwave and looking more closely at trap detectors for our fundamental calibration.

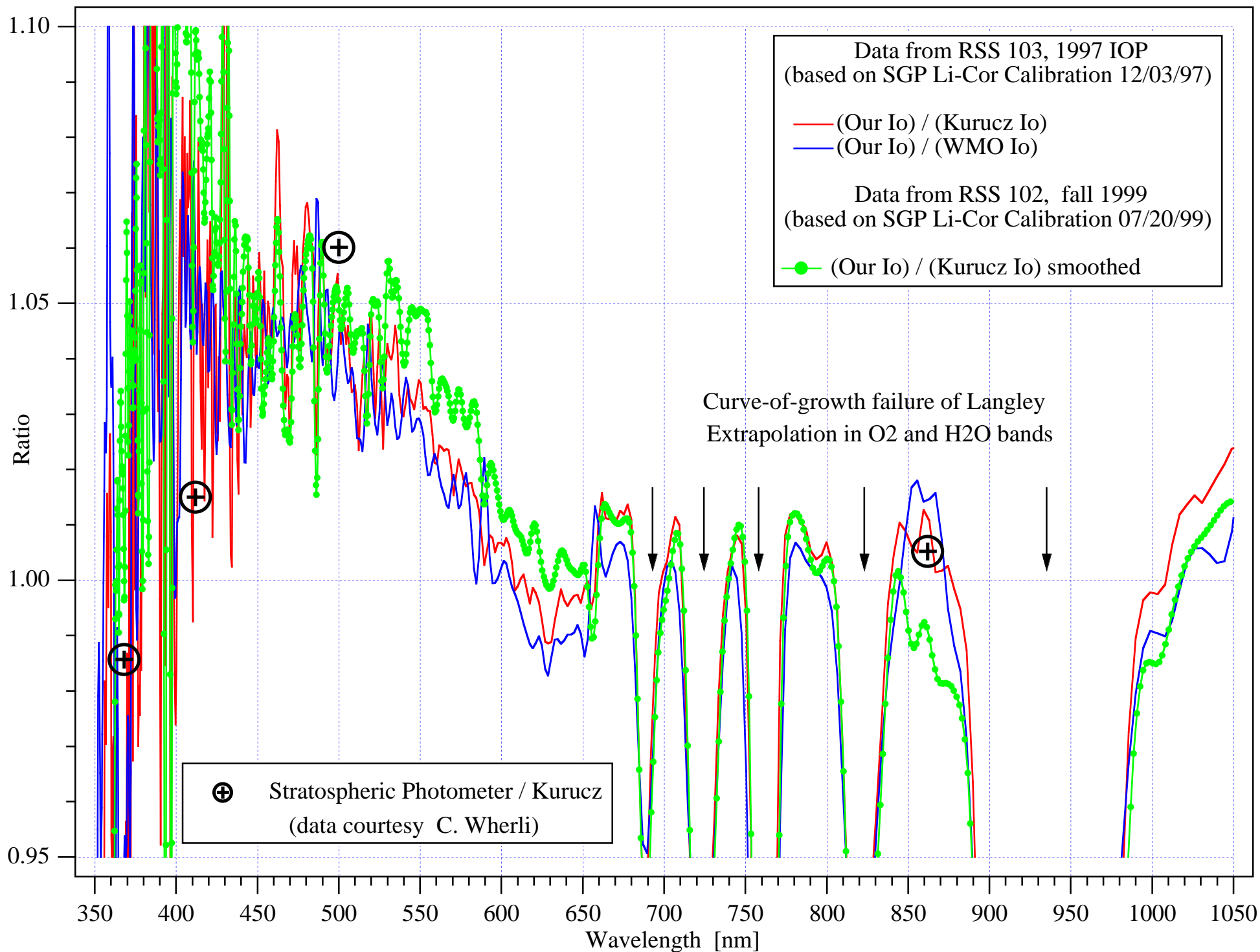
Our work on water vapor retrievals suggests to us that the spectroscopy of the near-infrared water vapor bands is still quite uncertain. This is not only important if one is trying to retrieve water vapor using these bands, but may be a source of small differences between irradiance measurements and irradiance models. We will continue to work on this issue. We expect to participate in the fall 2000 water vapor IOP with freshly calibrated MFRSRs and the RSS at the SGP site.

Lee Figure:

Using three NIST spectral lamps in 1997 and then six NIST spectral lamps in 1999 we have developed working standards for calibrating the RSS. This calibration yields the spectral irradiance per count at 512 (RSS 103) or 1024 (RSS 102) spectral elements. Through Langley analysis we can estimate the response of our RSS's in counts at the top of the atmosphere. By multiplying the calibration in spectral irradiance per count and the extraterrestrial response in counts we estimate the extraterrestrial (ET) solar spectral irradiance.

Comparisons are made in this figure with the widely used Kurucz ET spectrum and the WMO ET spectrum. The thin red and blue lines are the ratios for the 512-element RSS 103 that was calibrated with three NIST lamps in 1997 and Kurucz and WMO, respectively. The green line is the ratio for the 1024-element RSS 102 that was calibrated with six NIST lamps in 1999 and Kurucz. The dips that are off the chart are water and oxygen bands where our Langley analysis to get extraterrestrial RSS response in counts fails because of curve of growth problems.

Main point: there appears to be a broad deviation with a peak near 500 nm of 4% with our results higher. This is outside the limits that we have estimated for our uncertainty. Also plotted are points from a recent (not yet published) balloon flight with a sunphotometer that uses a trap-detector-based calibration. These points were kindly provided by Christoph Wehrli of the World Radiation Center in Davos and should be considered preliminary.



Joe Figure:

Aerosol optical depth has been measured since late 1992 at the ARM Southern Great Plains site in north central Oklahoma using a multi-filter rotating shadowband radiometer. Five of the seven channels, which are sampled simultaneously, are suitable for aerosol optical depth retrievals.

Each point on this figure represents a daily average of however many 30-minute cloud-free periods there are during the day. The dashed vertical lines are drawn at the year boundaries. Over nearly eight years we obtained just less than one point every other day. The solid line is a locally-weighted robust regression fit to the points; it gives more weight to the points near in time and is resistant to isolated outlying points. The winter minimums decrease initially and then stabilize. The higher winter values in 1992, 1993, and 1994 are associated with the stratospheric aerosol left over from the Mt. Pinatubo eruption. The most notable point about the summer peaks is their variability from year to year.

ARM SGP Central Facility Aerosol Optical Depth vs Time

